J. Environ. Nanotechnol.
Volume 8, No.2(2019) pp. 24 - 27
ISSN (Print): 2279-0748
ISSN (Online): 2319-5541
doi:10.13074/jent.2019.06.192360

Dye Sensitized Solar Cell With Natural Dye Extract from Beetroot

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Received: 18.10.2018 Accepted: 12.12.2018

Abstract

Solar cells have attracted increasing attention over the last decades. One of the emerging technologies in solar field is Dye Sensitized Solar Cell (DSSC). Dye Sensitized Solar Cells have been extensively used because they offer the advantages of low cost, lower toxicity, environmental friendly and low weight. DSSC is the most promising new generation system for photovoltaic technology. TiO_2 photo electrode is prepared by doctor blade technique and is sensitized using the beetroot extract as a natural sensitizer. The sensitizer is an essential component to absorb sunlight to its extent and convert the incident photons into electric current. With the counter electrode and electrolyte solution, the DSSC is fabricated. The UV and Current-Voltage characteristic has been studied and also the solar power conversion efficiency is found.

***Keywords**: DSSC, Beetroot dye, Doctor Blade Technique, UV and (I-V) characterization.*

1. INTRODUCTION

India has a vast potential of renewable energy sources. One of the non-conventional energy is solar energy. Sun is the best source of light and heat. The thermal energy radiated by the sun is inexhaustible. Hence the solar energy is called a renewable source of energy. It is believed that with 0.1 percent of the 75,000 trillion KWH of solar energy that reaches the earth, the planet's energy requirements can be fulfilled.

Solar cells are the important applications of solar energy. Solar cell is a device that converts sunlight directly into electricity by the photovoltaic effect. Dye Sensitized Solar Cells (DSSC) is also known as Third Generation Solar Cell or Gratzel Solar Cell. To utilize the solar energy to a maximum extent, it can only be achieved by the use of solar cells.

Dye sensitized solar cell (DSSCs) are receiving increasing attention from researchers because of their low-cost materials (Gokilamani *et al.* 2013). The operational principle of DSSC is very simple: The dye is the photoactive material of DSSC and can produce electricity once it is sensitized by light. The dye catches photons of incoming light and uses their energy to excite electrons. Then, it injects this excited electron into TiO_2, where the electron is conducted away by TiO_2. A chemical electrolyte in the cell then closes the circuit so that the electrons are returned back to the dye. It is the movement of these electrons that creates energy which can be harvested into a rechargeable battery, super capacitor, or another electrical device.

Solar cell system developed in this work is DSSC, composed of TiO_2 layer act as electron carrier, dye act as an electron generator, which will recover to its original state by the electrolyte solution. Fig.1 represents an ideal DSSC.

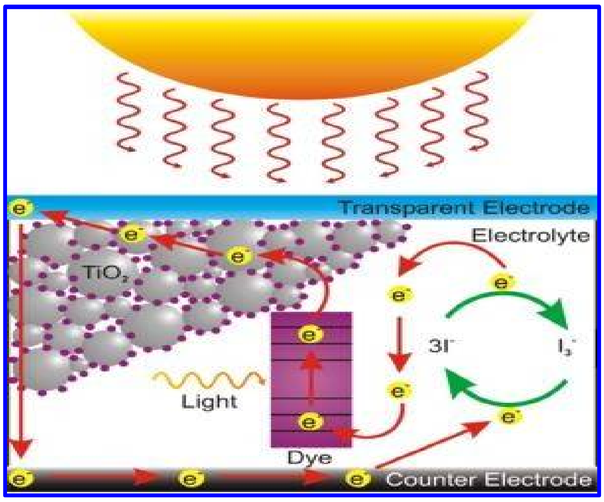

Fig. 1

India is rich in natural plant resources. Many

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plants possess the due products (Sathyajothi *et al.* 2017). These dyes can be utilized for various applications. In our research work, beetroot *(Beta vulgaris)* dye is used as sensitizer. It is prefer to be grown in moist, fertile soil in a sunny spot, but will also thrive in raised beds or pots. The pigments present in the beetroot are betanins, betalains, betacyanins, and betaxanthins, etc. Due to the presence of these pigments it gives the red or red-violet colour.

2. EXPERIMENTAL PROCEDURE

2.1 Preparation of TiO_2 Electrode (Photo Anode)

To prepare the photo anode (n-type) of dye sensitized solar cells, the Fluorine-Doped tin oxide (FTO) conducting glass substrate was cleaned in an ultrasonic digital cleaner using acetone for 15 minutes, then rinsed with distilled water and dried. Two edges of the FTO glass plate were covered with a layer of adhesive tape to control the thickness of the film and to mask electric contact strips (Gokilamani *et al.* 2013). A small quantity of TiO_2 paste was placed in the sealed area and is coated well on the FTO substrate by doctor blade technique. The TiO_2 substrate is annealed at 450 °C for one hour in a muffle furnace. This is the first coating. Again the same process was repeated for second coating. The photo anode is prepared.

2.2 Preparation of Natural Dye Sensitizer

In the present study, beetroot is used as a natural dye sensitizer. Beetroot is well cleaned and finely chopped. In a conical flask, the finely chopped beetroot were mixed with 50 ml of ethanol and is warmed at 45 °C for one hour. Then the residual parts were removed by filtration. This was directly used as natural dye solution for sensitizing the TiO_2 electrode. To sensitize the TiO_2 electrode, the dye solution was placed in a petridish and the TiO_2 coated FTO was immersed in the extracted dye solution at room temperature for 24 hours, so that the dye was absorbed inside TiO_2 active areas (Sathyajothi *et al.* 2017). The electrode was then rinsed with ethanol to remove the excess dye present in the electrode and dried in open air. The dye sensitized TiO_2 electrode is prepared.

2.3 Platinum Coated Counter Electrode

The counter electrode (p-type) material is a platinum coated Fluorine-Doped tin oxide (FTO) conducting glass substrate, in which a hole is drilled in it for the passage of electrolyte solution. This is called the platinum electrode or the counter electrode.

2.4 Assembly of Dssc

The dye sensitized solar cells were assembled by placing the counter electrode on the top of the TiO_2 electrode, such that the conductive side of the counter electrode faced the TiO_2 film with a spacer separating the two electrodes (Gokilamani *et al.* 2013). The two electrodes were clamped firmly together using a binder clip. High stability electrolyte (EL-HSE) was used as a liquid electrolyte solution. Now the liquid electrolyte solution was injected into the space between the clamped electrodes. The electrolyte enters into the cell by capillary action. This resulted in the formation of sandwich type cell.

Figure. (2)

Figure (2) represents the fabricated Natural dye sensitized TiO_2 solar cell with area of 0.4 cm^2, and it was found that the cell efficiency was independent of cell area. By illuminating the cells with a light source or sunlight, voltage across each individual cell can be measured (Sathyajothi *et al.* 2017).

3 RESULTS & DISCUSSIONS

3.1 Ultra-Violet Visible Spectroscopy

The UV visible spectroscopy was carried out to study the absorption spectroscopy. The figure 3.a and 3.b represents the absorption spectra of pure TiO_2 substrate, beetroot dye and dye sensitized TiO_2. The maximum absorption for pure TiO_2 is at 348.49 nm and that for beetroot extract is at 631.81 nm and that for the dye sensitized TiO_2 electrode is at 343.61 nm.

The band gap is calculated using the formula,

$$Eg = hc / \lambda$$

Where

Eg – Band gap energy,
h - Plank's constant (6.623*10-34 Joules/sec),
c – velocity of light (3*108 meter/sec),
λ - wavelength of the sample

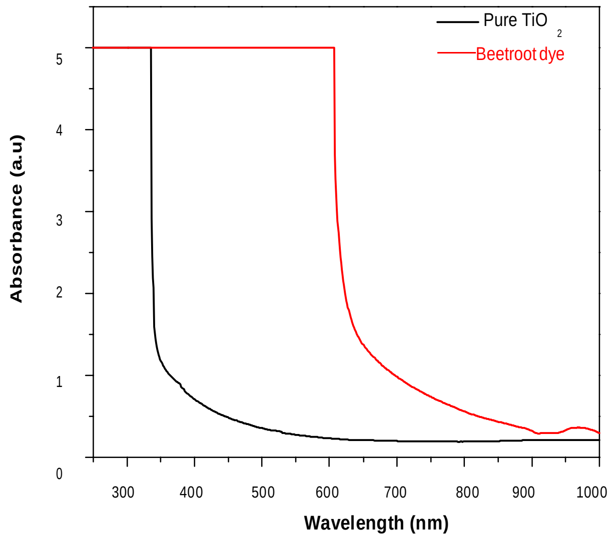

Fig. 3a

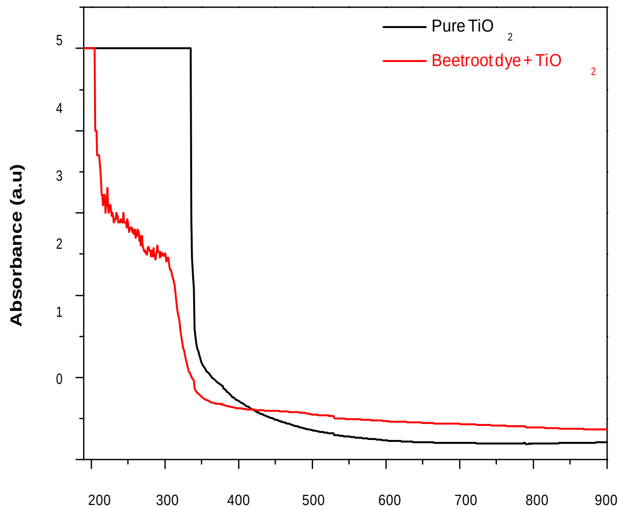

Fig. 3(b)

The calculated band gap of pure TiO_2 is 3.5eV and that of beetroot extract is 1.96 eV and for the TiO_2 electrode is 3.6 eV.

3.2 I-V Characterization

The current-voltage characteristics of DSSC define the operation within the electrical circuit. The I-V characteristic curve show the relationship between the current flowing through the DSSC and the voltage applied across its terminals. Figure.4 represents the I-V curve of the DSSC, which helps to determine and understand the basic Parameters such as short circuit current (I_{SC}), open circuit voltage (V_{OC}), fill factor (FF), and solar power conversion Efficiency (η). The voltage is applied to the DSSC up to 10 volts and the current is measured and the graphs are drawn, taking voltage in x-axis and current in y-axis.

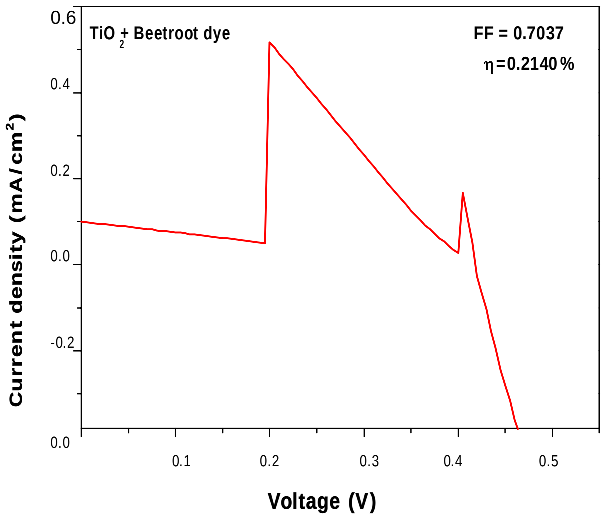

Fig. 4: I – V characteristics of DSSC

The efficiency parameters are tabulated in Table.1 and the efficiency is calculated using the formula,

$$\eta = P_{max} / P_{in}$$

Where, $P_{max} = V_{oc} I_{sc} FF$

$$\text{Hence, } \eta = V_{oc} I_{sc} FF / P_{in}$$

The input power for efficiency is 100 mW/cm^2.

Table 1.

Name of the dye	Open Circuit Voltage (Voc)	Open Circuit Current (Jsc)	Fill Factor (FF)	Solar Efficiency (η)
Beetroot dye	0.465	0.1	0.7037	0.2140%

Thus, the result of I-V characteristics show that the natural dye sensitized solar cell has solar efficiency of 0.21%.

4. CONCLUSION

Dye Sensitized Solar Cell has been successfully prepared. In this work, we have reported the fabrication of DSSC by doctor blade technique and the use of natural dyes and also reported its photovoltaic performance. The dye sensitized solar cells fabricated is of low cost, environmental friendly, Renewable and clean source of energy and non-pollutant. Thus, the DSSC prepared with Beetroot dye has an Efficiency of 0.21%. The result of this work is encouraging and it can be further taken into future research for increasing its efficiency using natural dyes.

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